# Community-Based Climate Change Adaptation Action Plans to Support Climate-Resilient Development in the Eastern African Highlands

Johansson, Tino Petri

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# Community-based climate change adaptation action plans to support climate-resilient development in the Eastern African Highlands

**Tino Johansson, Emmah Owidi, Sarah Ndonye, Sarah Achola, Weyessa Garedew and Claudia Capitani**

**Abstract** Smallholder farmers in the Eastern African Highlands depend on rain-fed agriculture for their livelihoods. Climate adaptation and sustainable development goals must be targeted in an integrated way to better match farmers' realities and address local priorities and vulnerabilities in these areas. To support climate-resilient development in the Eastern African Highlands, 224 local stakeholders were engaged in the development of community-based climate change adaptation action plans for the Jimma Highlands in Ethiopia, Taita Hills in Kenya and Mount Kilimanjaro in Tanzania. Participatory methods, high-resolution climate projections and the United Nations Development Programme's (UNDP's) guidelines were used in the design of these climate action plans with specific objectives to: 1) engage stakeholders to increase understanding of climate change impacts, adaptation options and their potential trade-offs, 2) build their capacities to design climate change adaptation projects, 3) empower stakeholders to identify existing vulnerabilities and enhance climate resilience and 4) strengthen networks to facilitate information access and sharing. Increased risk of water stress and reduction of agricultural productivity were the most frequently identified climate-change-induced problems in the three areas. The developed action plans target the underlying causes of these problems and describe sector-specific responses, activities, critical barriers and opportunities and support the National Adaptation Programmes of Action.

**Keywords** action plan · adaptation · climate change · Eastern Africa · resilience

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T. Johansson (✉)

Department of Geosciences and Geography, University of Helsinki, P. O. Box 68, 00014 Helsinki, Finland

e-mail: tino.johansson@helsinki.fi

tel. +358 (0) 2941 50825

E. Owidi · S. Ndonye · S. Achola

International Centre of Insect Physiology and Ecology, P. O. Box 30772, 00100 Nairobi, Kenya

e-mail: ejowidi@gmail.com sarah.ndonye@gmail.com sachola@icipe.org

W. Garedew

Jimma University College of Agriculture and Veterinary Medicine, P. O. Box 307, Jimma, Ethiopia

e-mail: weyessa2001@yahoo.com

C. Capitani

Environment Department, Wentworth Way, Heslington, University of York, York, United Kingdom

e-mail: claudia.capitani@york.ac.uk

## Introduction

The global ecological system has throughout history gone through tremendous changes, but never before have human activities had such a huge influence on the rate of change. Greenhouse gas emissions from fossil fuel combustion and industrial processes, deforestation, land use change, and agriculture are the biggest culprits of global warming. Around the world, meteorological observations indicate an increase in annual average temperatures. The biosphere and its complex climatic system dynamics generate short-term events, such as erratic rainfall patterns, longer dry spells, floods, and tropical storms, which can also negatively affect our livelihoods. Global and regional changes in temperature and rainfall can provide suitable conditions for flora and fauna to shift their geographical range to areas where these were unknown or rare decades ago. However, climate change is not the only phenomenon that has impacts on our environment. Human-induced land use change is an equally important driver, for example, in the reduction of the amount of freshwater resources available for the growing population.

One of the challenges in climate change mitigation and adaptation is to establish a clear link between local activities and the global phenomenon, which is often considered as an exogenous force by the people influenced by its impacts. National climate change strategies provide a framework of action and share responsibilities to different authorities to address sector-specific interventions that operate at a level inaccessible by the smallholder farmers and other vulnerable groups mostly affected by climate change impacts in Africa and elsewhere in the Global South. This usually positions farmers to the role of passive recipients of information and top-down adaptation action plans from the government. Farmers' realities, local priorities or village-scale vulnerabilities are rarely included in national climate change strategies, which make it difficult for the grass-roots-level stakeholders and communities to adopt an active role in implementation and ownership of adaptation initiatives. In this chapter, an alternative approach is presented where 224 local stakeholders, including smallholder farmers' representatives, were fully engaged in the development of community-based climate change adaptation action plans for three highland areas in Eastern Africa, namely for Jimma Highlands in southwest Ethiopia, Taita Hills in southeast Kenya and Mount Kilimanjaro in northern Tanzania. This collaboration between scientists, local stakeholder organizations and farmers aimed at integrating different knowledge systems, scientific and indigenous, to understand climate change impacts at the local level and to prioritize adaptation actions and designate locations of the most vulnerable areas for implementation. The objective was to build communities' resilience to climate change through a participatory process for the co-production of knowledge.

The chapter begins with a brief description of climate change impacts in the highlands of Eastern Africa to provide an overview of challenges faced in freshwater provision and agricultural production there. A case study on climate change impacts on coffee production in Jimma, Ethiopia projects a shift in the area suitable for this important cash crop and increasing loss of yield due to plant diseases and insect pests in the country. After this general overview, the chapter focuses on the description of the actual process of community-based climate change adaptation action plan development, the aim and scope, design and methods used and the key findings and content of the three action plans. In the end, the chapter further discusses the potential of using high-resolution climate change models in association with socioeconomic scenarios as a tool to understand and capture the complexity of interactions and feedback between climate and other factors. A case study on the use of participatory scenarios describes how these facilitated the development of three alternative adaptation pathways in response to projected climate change in Jimma Highlands and Taita Hills.

## Climate change in the Eastern African Highlands

The headwaters or sources of the largest rivers in Africa, such as the Nile, Niger, Congo and Orange, are located in the mountains and highlands. The vast amount of water in these rivers is probably the greatest manifestation of an invaluable ecosystem service that sensitive highlands and mountains provide to people. However, water provision is seriously threatened by accelerating land cover/land use change on the upper slopes where most of the remaining mountain forests are located. The capacity of these mountain ‘water towers’ to store moisture, supply freshwater to the lowlands and reduce peak flood flows during extreme weather events has been compromised mainly by human activities, such as deforestation. These impacts are amplified by increasing temperatures and variability in rainfall due to climate change, which contributes to glacier melt and reduced surface water capacity of the watersheds. Over 50% of the world’s population today benefits directly or indirectly from mountain resources and services (Chand and Leimgruber 2016).

Africa is a particularly vulnerable continent to climate change and climate variability because it is home to many poor and marginalized communities that have low adaptive capacity. Climate variability, such as the El Niño event, and long-term climate change have caused significant impacts on the social-ecological systems across the continent. The situation is further aggravated by existing socioeconomic challenges, such as limited access to capital and markets, infrastructure and technology. Agriculture, a sector that is highly susceptible to climate change impacts, is the main source of livelihood for most people in Africa. It also accounts for a large percentage of the gross domestic product in many African countries. In sub-Saharan Africa, food production remains largely dependent on rain-fed agriculture, which covers more than 95% of all cultivated land. The level of food production remains low due to many reasons, such as degraded soils, droughts and floods that can be attributed to the changing climate and land use/land cover change.

In Eastern Africa, increased temperatures, late onset and early cessation of rains and extreme climatic events continue to negatively affect agriculture through reduced crop and fodder production, damage by pests and diseases, and contributing to water logging and soil erosion. Variability in rainfall is the most often perceived impact of climate change by smallholder farmers who rely on rain-fed agriculture for subsistence. The livelihood of these people highly depends on climate-sensitive resources making them most vulnerable to climate change impacts. Late onset and early cessation of rains during the expected rainy season currently challenge and limit food production and make it difficult for the farmers to decide when to carry out preparations for planting. Higher annual average temperatures are projected to worsen the impact of insect pests on staple and cash crop production because of increased survival, reproduction and growth rates of the insects, as well as their potential geographical range shift to different agroecological zones.

There is urgency to implement adaptation strategies that bring immediate benefits and help overcome the limited adaptive capacities to climate change impacts and, by doing so, contribute to economic growth and development. Effective adaptation responses focus on reducing or limiting exposure to risks, lowering vulnerability and enhancing the resilience of communities and sectors to these impacts. Various adaptation strategies are available, however, for the poorest communities; sustainable and low-cost options should be preferred. Community-based adaptation approaches are necessary because the benefits of adaptation must be immediate and relevant to communities by addressing local priorities and vulnerabilities to existing climate conditions. Therefore, it is critical that the knowledge, experiences and perceptions of local communities concerning climate change and variability are incorporated in the design of adaptation strategies.

**Case study 1: Impact of climate change on coffee production in Jimma, Ethiopia**

In Ethiopia, historical climate data show an increase in mean annual temperature by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade (McSweeney et al. 2010) and by 0.3°C per decade in the southwest of the country (Jury and Funk 2013). Such change will seriously challenge the agricultural sector in the coming decades because many crops are sensitive to water shortage and heat stress (Ramirez-Villegas and Challinor 2012). Climate change impacts will seriously hamper the production of important cash crops, such as coffee, which serve as the economic foundation for many tropical countries and on which millions of farmers' subsistence depends. In Ethiopia, coffee farming provides a livelihood for about 15 million small-scale farmers and generates 25% of the country's export earnings. Coffee is an important cash crop that generates income for the farmers to pay for children's school fees and to buy food when their own staple crop yield is too low to feed their families.

An increase in temperature and precipitation variability will decrease coffee yield, reduce its quality and increase pest and disease pressure on this valuable cash crop (Ovalle-Rivera et al. 2015). Climate change impacts on coffee production are very site-specific for each geographic region. In the near future, some areas will become unsuitable for coffee production, while other areas that remain suitable must adopt new agricultural practices to adapt coffee farming to the impacts of climate change. However, climate change will also open new areas for coffee production as conditions become suitable for its cultivation (Linne et al. 2010). In Eastern Africa, suitable climatic conditions for Arabica coffee production are predicted to shift from 400–2000 meters above sea level (m.a.s.l.) to 800–2500 m.a.s.l. (Ovalle-Rivera et al. 2015). Studies on the spatial shifts of suitable climatic envelopes for coffee (Davis et al. 2012; Ovalle-Rivera et al. 2015) indicate that one response is the migration of people and coffee to suitable areas if opportunities exist, but the response may also include changing livelihood practices in areas of decreasing climatic suitability for coffee.

Significant research efforts have been taken to predict the effect of climate change on coffee production systems in the tropics (Davis et al. 2012; Jaramillo et al. 2013; Moat et al. 2017). Arabica coffee has its indigenous origin in the forests of the Jimma area in southwest Ethiopia where the latest high-resolution ensemble climate projection for 2041 to 2070 indicates a hotter future with more extreme dry and wet seasons (Platts et al. 2014). Arabica coffee has a relatively narrow envelope of climatic suitability, which means that the bioclimatically suitable area for this native coffee species could decline dramatically in Ethiopia in the coming decades. Davis et al. (2012) indicate that climate change will continue to reduce the production of wild Arabica coffee in Ethiopia from 65 to 100% less in the number of recorded suitable sites for the existence of wild coffee plants by 2080. Similarly, Moat et al. (2017) reported that 39–59% of the current growing area could experience climate change large enough to render them unsuitable for coffee farming in Ethiopia, in the absence of significant interventions or major influencing factors. Conversely, the report indicated that relocation of coffee areas, in combination with forest conservation or re-establishment, could experience at least a fourfold increase in suitable coffee farming area.

Climate change also triggers changes in diversity, abundance and population dynamics of coffee pests and diseases in Ethiopia (Jaramillo et al. 2013). The incidence and severity of one of the major pest insects for coffee, namely the coffee berry borer *Hypothenemus hampei* (Ferrari), is projected to increase in Ethiopia, reducing yield and quality and increasing production costs (Jaramillo et al. 2009). A study conducted in the Jimma area from 2013 to 2015 indicated that a disease, coffee leaf rust caused by *Hemilleia vastatrix*, is progressing to higher altitude areas where the symptom has never been expected before. The symptom of the disease was recorded exceptionally at ca. 2100 m.a.s.l, consistently over the 3 years of study.

## Community-based climate change adaptation action planning

Climate change impacts are not uniform across the African continent but vary between regions and are site-specific. The increasing intensity and frequency of climate change impacts in Eastern Africa have generated the need to develop locally relevant climate change adaptation response strategies. Rather than exclusively depending on existing national adaptation plans and regional strategies, the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report recommends for place- and context-specific adaptation as well as complementary actions across different scales, from individuals to governments (Field et al. 2014). Therefore, community-based adaptation action plans complement the higher-level strategies while taking into consideration unique local priorities and needs, knowledge and experiences. Another key feature of such adaptation action plans is that they can be implemented locally with minimal costs, resources and expertise and are more acceptable to local communities. A key component of successful development of action plans is to bring together relevant local and regional stakeholders to identify and prioritize adaptation options in collaboration. This is especially important among rural communities to help them cope with experienced site-specific climate impacts in a timely manner.

The Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project http://chiesa.icipe.org/ coordinated by the International Centre of Insect Physiology and Ecology (*icipe*) in Nairobi, Kenya facilitated a consultative process involving local communities and institutional stakeholders in three mountain communities: the Taita Hills in Kenya, Mount Kilimanjaro in Tanzania and Jimma Highlands in Ethiopia. Through a set of participatory methods, the project supported and guided local stakeholders to formulate adaptation action plans for these selected target areas. The focus was on adaptation actions that can reduce the vulnerabilities and enhance the social resilience of local communities to cope with the impacts of climate change and variability. Vulnerability reduction is critical to adaptation (Field et al. 2014), so identification of the underlying causes rather than focusing on responses to the more obvious immediate causes is important to prevent the recurrence of problems by targeting the reduction of specific vulnerabilities (Wisner et al. 2004).

### Aim and scope of community-based climate change adaptation action plans

Development of community-based climate change adaptation action plans in the three CHIESA project sites was based on the need to build the capacities of local communities and institutions to adapt to the current and projected climate change impacts. The co-production of community-based climate change adaptation action plans aimed at increasing understanding of the dynamic interaction between people and environment. In addition, the social resilience approach aimed at identifying resources and inherent capacity of the communities that can be utilized to overcome problems caused by climate change as well as by non-climatic drivers. A participatory, consultative process involving community and institutional stakeholders was undertaken to identify critical climate-induced challenges in each area as well as to recommend suitable and evidence-based adaptation options in response to the prioritized challenges. The adaptation action plan development was guided by the following objectives:

1. Increasing communities' understanding of the causes and impacts of climate change and adaptation options.
2. Building capacities of the target communities to design gender-disaggregated adaptation responses.
3. Enabling communities to identify vulnerabilities and enhance their resilience to climate change.
4. Strengthening networks to facilitate information access and sharing on climate change issues at local and national levels.

Participants who contributed to the planning, design and development of the action plans in the three areas included different stakeholders, beneficiaries and end-user groups within the communities, such as farmers, water resource users, forest resource managers and self-help groups. The institutional participants represented community-based organizations, non-governmental organizations, local and national government and research and development institutions working in climate-sensitive sectors, such as agriculture, water, forestry, development and planning. Furthermore, the process supported active participation of women, youth and people with disabilities, who are often considered the most vulnerable groups to climate change impacts (Field et al. 2014; Dazé et al. 2010) but are often overlooked in decision making.

The adaptation action plans aimed not only to identify appropriate adaptation responses for different stakeholder groups, such as community groups, based on their specific needs and priorities (King 2014) but also to link the recommended adaptation responses to specific underlying vulnerabilities and local knowledge. An emphasis on maximum stakeholder participation ensured that the developed adaptation action plans are relevant and acceptable to the majority of stakeholders and are sustainable in the longer term (Dazé et al. 2010). By examining the root causes of climate-induced problems, the recommended adaptation responses focused on long-term rather than short-term priorities (UNDP 2010; Field et al. 2014), while empowering the most vulnerable people with necessary knowledge, skills, resources and opportunities to cope with the challenges. Furthermore, the adaptation action plan development process captured local knowledge on climate change and integrated this with both the scientific knowledge from previous research work carried out in the areas and the national and regional climate change response strategies as recommended in the IPCC Fifth Assessment Report (Field et al. 2014). The adaptation action plans are also supported by the relevant existing National Adaptation Programmes of Action, climate change strategies, policies and frameworks, thereby making it easier to integrate these action plans into the national implementation programs in the target areas.

## Design and methods used in action plan development

The community-based climate change adaptation action plans for the three highland target areas in Eastern Africa were developed between December 2013 and August 2015. A total of 218 participants were involved in the co-production process. Of these participants, 31% were women and 24% were disabled persons. Overall, a total of 91 local community-based organizations, non-governmental organizations and governmental institutions were represented. The objective was to facilitate involvement of a wide range of community and institutional stakeholders in the process to better ensure integration of the developed action plans into existing adaptation knowledge and networks (King 2014) as well as to consider vulnerable social groups, such as women (Field et al. 2014), and to strengthen the inherent capacities and facilitate networking of different stakeholders (King 2014). As a result, 18 workshops and focus group discussions, 4 field visits and 1 stakeholder exchange visit between the Taita Hills and Mount Kilimanjaro stakeholders were conducted. During the workshops, participants were divided into mixed groups consisting of both genders and representing different altitude zones in the project target areas and different livelihood activities and sectors of society. Initially, separate workshops were conducted for the groups of disabled persons to capture their unique perspectives. However, joint validation workshops were conducted during the final stages of the adaptation action plan development. The generated knowledge and ideas were synthesized to formulate the recommended adaptation action plan responses.

The United Nations Development Programme's (UNDP's) Climate Change Adaptation Toolkit was used in the design of the adaptation action plan development process. The Toolkit proposes a six-step logical process for designing adaptation initiatives. This includes 1) defining the problem, 2) identifying causes, 3) articulating normative responses, 4) identifying key barriers to overcome in reaching the desired situation and 5) designing appropriate responses to achieve the desired solutions. Stakeholder participation is emphasized as a key component throughout the project cycle (UNDP 2010). As a result, different participatory methods were used (King 2014) at these steps of the adaptation action plan development to collect local knowledge and perspectives on climate change impacts, identify adaptive capacities and underlying causes of vulnerability and assist in making adaptation decisions suitable for different livelihoods and social groups. The tools were adapted from existing climate change adaptation tools, such as CARE International's Community-Based Adaptation Toolkit (CARE 2010), Participatory Monitoring, Evaluation, Reflection and Learning for Community-based Adaptation Manual (CARE 2014) and Energie Environnement Développement and Stockholm Environment Institute Adaptation Toolkit (Ampomah and Devisscher 2013). Additionally, the Problem Tree Analysis was used to identify key climate-change-induced problems and to investigate their underlying causes. A mapping tool was used to spatially locate vulnerable resources and social elements at risk from the climate-change-induced problems and to identify existing capacities to implement solutions for the problems. The Participatory Scenario Building tool was used to help community members plan for the future and make adaptation decisions based on their past experiences, current inherent capacities and available assets and their vision and goals for the future. In the end, the Adaptation Visioning Tool was utilized to identify the challenges and opportunities for adaptation, design responses to overcome key barriers and identify the overall goal for implementing the adaptation initiatives and establishing the stakeholder roles and responsibilities.

Participatory selection and prioritization of climate change adaptation action sites by the stakeholders was part of the process of linking local and scientific knowledge. Data on the prioritized climate change adaptation action sites were collected with the participatory Geographical Information Systems (GIS) method from the communities and stakeholders and were visualized and shared with the local partners to guide establishment of demonstration sites in the most optimal locations, such as critical areas where actions and interventions need to be taken against experienced climate impacts and negative changes. Representatives from different groups, such as national and county governments, non-governmental organizations, water user associations, women's self-help groups and disabled person groups, actively contributed by sharing their observations and experiences on the local areas and sites where urgent adaptation actions were in high demand. Later, the observations were digitized, converted into geospatial layers, embedded and visualized as story maps in the web map application Multifunctional Agricultural Landscape Mosaics (MALM), which was established on a free online platform for upscaling and disseminating information to other users and decision makers.

The results of the participatory mapping approach were compiled through a GIS-based suitability analysis to map priority areas for the key interventions, such as roof rainwater harvesting, drip irrigation, agroforestry and tree planting, conservation agriculture and insect pest management. The suitability analysis was based on multi-criteria overlay analysis. For each intervention type, a set of evaluation criteria were determined, and corresponding decision rules and weights were determined and applied to make the final maps. For example, the suitability of agroforestry and tree planting was mapped based on land use/land cover maps to concentrate on agricultural areas, forest connectivity analysis was used to improve the ecological connectivity between the remaining forest patches, and distance to the rivers was used to support reforestation of the riparian areas.

## Key findings of action plans

### Climate-change-induced problems in the target areas

Five major climate-change-induced problems were identified and prioritised in the target areas. They were water shortage and reduced crop yields in the Taita Hills; increased frequency of drought and floods in Mount Kilimanjaro; and land degradation in the Jimma area. These identified problems point out a strong local perception of changing rainfall patterns, which is in agreement with the IPCC Fifth Assessment Report (Field et al. 2014). Furthermore, all the problem statements formulated from the key climate-change-induced problems in the three areas are linked to threatened food security, livelihood and health. Emphasized impacts included poverty, hunger and malnutrition; lowered food security; reduced crop productivity; and negative changes in livelihoods in Taita Hills, Mount Kilimanjaro and Jimma, respectively. Such negative impacts of climate change on crop yields and food security have already been reported in many regions globally. Africa is particularly at risk due to overreliance on rain-fed crop production, high seasonal climate variability, recurrent droughts and floods and limited adaptive capacity due to poverty (Field et al. 2014).

Many other social-ecological problems were emphasized by the participants and linked to climate change in the target areas (Table 1). Common problems, such as decreased water availability, increased rainfall variability, increased frequency of floods and droughts, reduced crop yields, reduced animal numbers for livestock, increased land degradation, loss of biodiversity and increased incidence of pests and diseases, were experienced in all three areas. Such impacts are critical and should be considered in national and regional adaptation planning. However, some climate-change-induced problems were location-specific, such as melting snow cover and glaciers and reduced hydro-electric power (HEP) generation in Mount Kilimanjaro in Tanzania. Taita Hills and Jimma Highlands do not reach similar altitude as Kilimanjaro, the highest mountain in Africa, so there is no snow formation in these two areas. Certain identified problems, such as increased natural disasters and infrastructural damage, may be associated with increased extreme climatic events as well as the topography with steep terrain.

Table 1. Identified climate-change-induced problems in Taita Hills, Mount Kilimanjaro and Jimma.

| **Climate-change-induced impacts** | **Taita** | **Kilimanjaro** | **Jimma** |
|---|---|---|---|
| Decreased water availability | X | X | X |
| Increased inter- and intra-seasonal rainfall variability | X | X | X |
| Decreased rainfall | X | X | - |
| Increased (flash) floods frequency | X | X | X |
| Increased drought and dry spells frequency | X | X | X |

| | | | |
|---|---|---|---|
| Increased average temperature | - | X | - |
| Melting snow cover | - | X | - |
| Increased evapotranspiration | - | X | - |
| Reduced crop and livestock yields | X | X | X |
| Increased land degradation, soil erosion, siltation, soil fertility loss | X | X | X |
| Decreased food security | X | X | X |
| Reduced crop-growing season and unpredictable planting seasons | - | X | - |
| Biodiversity loss (forests, wildlife, fish, pollinators) | X | X | X |
| Increased (crop, livestock and human) pests and disease incidences | X | X | X |
| Increased cost of living, poverty and malnutrition | X | X | |
| Negative human and livestock health impacts | X | - | X |
| Increased (human-human and human-wildlife) conflicts over water | X | X | - |
| Increased human and wildlife migration | X | - | X |
| Increased encroachment and illegal settlements | X | - | X |
| Increased natural disasters and infrastructural damage | X | X | X |
| Lowered HEP generation capacity | - | X | - |
| Increased domestic/social problems | X | - | - |

It was difficult to pin-point any particular climate-change-induced problem to be the most important in the target areas because many problems are interconnected and form a complex cause-effect web. For example, reduced crop yields may be a consequence of rainfall variability, soil fertility loss, shortened growing seasons, uncertainty in farming calendars and increased pest damage and diseases. Non-climatic factors may also contribute to many of the identified problems. For example, decreased water availability may be attributed to overexploitation, deforestation, degradation of water resources and increased demand. Hence, there should be an active focus on reducing non-climate stressors on water resources to avoid additional impacts. Moreover, the findings suggest the adoption of integrated adaptation approaches that bring together different sectors and focus on building resilience, such as ecosystem-based adaptation (Field et al. 2014).

**Causes and consequences of the identified problems**

The immediate, underlying and root causes of the climate-change-induced problems were identified in the three target areas. The developed adaptation action plan responses focus on the immediate and underlying causes, which were considered as the direct drivers of local vulnerabilities to climate change impacts. However, addressing the root causes was beyond the scope of the project at the local scale. UNDP's six-step approach highlights the criteria for identifying causes including factors that are context-specific and time bound, institutional drivers and attitudinal and behavioural drivers. Each problem was explored exhaustively to identify the direct technical causes (immediate causes), the result of resource uses and practices and related social and economic drivers (underlying causes) as well as the system-level issues (root causes) (UNDP 2010). Both climatic and non-climatic causes were identified for each of the problems. However, this process mostly focused on identifying solutions for only the highest prioritized causes due to the large volume of information generated. Table 2 summarizes the prioritized immediate and underlying causes of climate-change-induced problems in the three target areas.

The direct technical causes identified are deforestation and removal of vegetation cover, uncontrolled grazing, irrigation expansion and pollution of water sources. The majority of the underlying causes identified by the stakeholders are anthropogenic and related to changes in resource use patterns and practices, such as degradation and over-exploitation of land and water resources, poor agricultural practices and changes in land cover. Other causes may be attributed to the changing demographic factors and socioeconomic pressures. The introduction of exotic trees and removal of indigenous trees in Taita Hills and Jimma Highlands largely take place due to the need for quick economic returns and inadequate awareness of sustainable agriculture and land management practices. However, certain identified causes may be considered to be beyond the scope of the community-based adaptation action plans due to their macro-level nature and can be categorized among root causes. For example, conflicting and un-harmonized catchment management policies and inadequate extension services were highly contested as underlying causes because implementing any responses would be beyond the capacity of local-level stakeholders. This challenge arose because it was extremely difficult for the local stakeholders to strictly delineate all the identified causes within the three categories of causes due to their closely interrelated cause and effect nature. However, such macro-level causes may be used to inform higher-level adaptation strategies. It is also interesting that certain factors, such as soil erosion were identified as both a problem and a cause. This reiterates the need for accurately assessing the linkages between causes and effects of the problems (UNDP 2010).

Table 2. Immediate and underlying causes of climate-change-induced problems in Taita Hills (1), Mount Kilimanjaro (2) and the Jimma area (3).

| **Immediate and underlying causes of climate-change-induced problems** | **Study site** |
|---|---|
| Increased land demand and expansion of farmlands and settlements | 1, 2, 3 |
| Inadequate soil and water management technologies and infrastructure | 1, 2, 3 |
| Poor cultivation and livestock-keeping methods and technologies | 1, 2, 3 |
| Land use change and unsustainable land use practices | 1, 2, 3 |
| Deforestation and removal of vegetation cover | 1, 2, 3 |
| Encroachment and over-exploitation of water catchment areas | 1, 2 |
| Un-harmonized catchment management policies and inadequate law enforcement | 1, 2 |
| Introduction of exotic tree species and removal of indigenous trees | 1, 3 |
| Need for immediate sources of income and food | 2, 3 |
| Loss of traditional methods of catchment protection | 1 |
| Expansion of irrigation | 1 |
| Increased demand and competition on water | 1 |
| Pollution of water sources | 1 |
| Destruction of useful insects and pests and increase of pests | 1 |
| Corruption and inadequate management of water resources | 1 |
| Increase of extended dry spells | 2 |
| Inadequate extension services | 2 |
| Increased charcoal, firewood and timber demand and inadequate alternative energy | 2, 3 |
| Poor planning of local drainage systems | 2 |
| Soil erosion | 3 |
| Uncontrolled grazing and overgrazing | 3 |
| Inadequate access to alternative livelihood activities | 3 |

**Preferred sector-specific responses, barriers and opportunities to implementation**

The prioritized responses to address the immediate and underlying causes of climate-change-induced problems in each site are listed in Table 3. These cut across different sectors and spatial scales and are implementable from the short-term to long-term by local stakeholders if provided with adequate knowledge, skills and resources. This does not necessarily mean complete reliance on external interventions but rather empowering and harnessing existing inherent capacities of communities to address the causes locally. The role of enhanced information access to communities and strengthened capacity of local institutions were considered most critical in all the target areas to address climate-change-induced problems. Conservation and restoration of degraded catchment resources through initiatives, such as tree planting and rehabilitation of riverbanks and springs, were also preferred in all sites. Moreover, in Taita Hills and Mount Kilimanjaro, stakeholders proposed the need for protection of threatened catchment resources, such as forests and springs, by clear delineation and demarcation to prevent encroachment. For example, due to the importance of the Miwaleni Springs as a major water source to downstream communities in Mount Kilimanjaro, stakeholders suggested its fencing and provision of security to prevent interference by humans and livestock. Another response considered critical in Taita Hills and Jimma was strengthening access to alternative livelihood and income-generating activities including enhanced communities' access to non-timber forest products, such as honey and medicinal herbs, to minimize pressure on ecosystems due to over-reliance on farming.

Table 3. Preferred adaptation responses in Taita Hills, Mount Kilimanjaro and Jimma Highlands.

| **Preferred adaptation responses** | **Taita** | **Kilimanjaro** | **Jimma** |
|---|---|---|---|
| | **Priority level** | | |
| Education and awareness on environmental conservation | High | High | High |
| Strengthen capacity of local institutions | High | High | - |
| Conservation and restoration of degraded catchments | High | High | Medium |
| Enhance access to alternative livelihood options | High | - | High |
| Establish mechanisms for monitoring water demand | High | - | - |
| Implement soil and water conservation practices | High | - | Medium |
| Protection and rehabilitation of water catchment resources | Medium | Medium | - |
| Delineation and demarcation of forests and springs | Low | High | - |
| Strengthen collaboration between local stakeholders | Medium | - | - |
| Introduce incentives and subsidies to protect catchments | Medium | - | - |
| Introduce sustainable farming methods and intensification | Medium | - | Medium |
| Promote access to sustainable and low-cost technologies | Medium | - | - |
| Design and implement land use plans | Medium | - | Medium |
| Improve livestock production technologies | - | - | Medium |
| Enhance income generation from natural forests | - | - | Medium |
| Discourage planting of exotic species | - | - | Medium |
| Maintenance of water management infrastructure | - | Medium | - |
| Harmonize national, local and cross-sectoral policies | Low | - | - |
| Strengthen enforcement of catchment management laws | Low | - | - |
| Construction of small earth dams ('chaco dams') | - | Low | - |

Different institutional and governance-related responses were also suggested to address climate-change-induced problems. For instance, in Taita Hills, strengthening collaboration among stakeholders was considered necessary. Further preferred institutional responses in the area included establishment of mechanisms for monitoring water demand; introduction of incentives and subsidies to protect catchments; harmonization of conflicting national, local and cross-sectoral policies related to catchment management; and strengthening the enforcement of catchment management laws. In addition, designing and implementing existing land use plans was also suggested in Taita and Jimma. A number of technological responses were preferred in the three areas, too. These were introduction of 'climate-smart' farming practices, such as conservation agriculture, integrated pest management and agroforestry in Taita Hills and sustainable intensification of farming systems and improved livestock management practices in the Jimma area. Other preferred technological responses were promotion of access to and implementation of low-cost technologies, such as drip irrigation, soil conservation and rain water harvesting. These responses were related to suggested infrastructural interventions in Mount Kilimanjaro, such as construction of small earth dams and maintenance of water management infrastructure, for example, by lining irrigation furrows to reduce water loss. Traditional irrigation methods are not very efficient in water use, and a large amount of freshwater is lost, so modern irrigation solutions, which are more efficient in water use, should be introduced and widely adopted. Due to the interlinked nature of preferred responses, integrated approaches involving different sectors and stakeholders were recommended to ensure success in implementing the adaptation action plans.

For successful implementation of the preferred responses, many critical barriers must be overcome. Identification of these barriers helps illuminate why preferred responses have not already been successfully implemented by previous interventions, if any, to prevent similar situations from recurring (UNDP 2010). Therefore, critical barriers were identified for each of the preferred responses and categorized according to their characteristics. The majority of the key barriers were recurrent in the three areas and related to technical capacity, physical factors, financial resources, attitudes and behaviour, technological factors, governance, institutional and political factors and social factors. For example, negative attitudes and resistance to new technologies were identified as key barriers across the areas. Technical capacity barriers included inadequate knowledge and skills within communities to implement responses, poor access to information and shortage of local experts, such as extension officers. Financial barriers in all the areas included inadequate funds to implement responses, while technological barriers identified were inadequate access to alternative technologies and high costs of technologies. Governance and political barriers in all the areas included weak law enforcement at the local level, low political goodwill and commitment to implement responses and corruption. Institutional barriers included weak institutions, inadequate monitoring of projects, shortage of staff, low budget allocations for local issues and inadequate collaboration between institutions. Social barriers included population pressure, increased resource demand and cultural beliefs and practices and high poverty levels, while physical barriers consisted of steep topography and high rainfall intensity.

Different opportunities for the successful implementation of adaptation responses were identified across the areas (Table 4). These include presence of organized community-based groups, such as Water Resource Users Association and Community Forest Association in Taita Hills; Water Users Association in Mount Kilimanjaro; and *kebele* (neighbourhood administration) in Jimma Highlands. Further opportunities include the availability of local extension systems. In Jimma, the Development Agents and Subject Matter Specialists are part of the agricultural extension system. However, extension services have greatly decreased in the last few years in Taita Hills and Mount Kilimanjaro, with the promotion of demand-driven extension where the agents only act when invited for a visit by a community or an individual farmer who has faced problems with, for example, plant disease or invasive crop pest. This change has added cost of the extension service to the customers and raises questions about the affordability of such service to poor smallholder farmers in the highlands. Other opportunities for adaptation include availability of indigenous knowledge, such as traditional bee-keeping in Jimma as well as indigenous crops and livestock breeds adaptable to local conditions in Mount Kilimanjaro and Taita Hills. Additionally, other identified opportunities are suitability of local climatic and agroecological conditions, existence of reliable water sources and willingness of communities to adopt new technologies, to learn new ideas and to participate in local initiatives.

Table 4. Opportunities for successful implementation of preferred adaptation responses.

| **Opportunities for successful adaptation responses** | **Taita Hills** | **Kilimanjaro** | **Jimma** |
|---|---|---|---|
| Adaptable indigenous crops and livestock breeds | X | X | X |
| Existence of community-based groups | X | X | X |
| Conducive local climatic and agroecological conditions | X | X | X |
| Existence of indigenous knowledge | X | X | X |
| Existence of water sources (e.g. springs, rivers, rainwater) | X | X | X |
| Communities' willingness to adopt new technologies | X | X | X |
| Communities' willingness to learn and participate in actions | X | X | X |
| Alternative sources of fuel (e.g. wind, HEP, biogas) | X | X | - |
| Availability of local material | X | X | - |
| Availability of low-cost technologies (e.g. cook stoves) | X | X | - |
| Existence of key farmers to facilitate extension | X | X | - |
| Availability of tree nurseries and indigenous tree seedlings | X | X | - |
| Adequate labour from youth population | X | - | X |
| Improved marketing systems | X | - | X |
| Existence of Farmer Training Centres (FTC) | X | - | X |
| Existing good practices (e.g. soil and water conservation) | X | - | X |
| Enabling policies, political support and good governance | - | X | X |
| Presence of research centres and universities | - | X | X |
| Adequate and improved settlement areas and farmlands | - | X | - |
| Adequate land in upper zones for developing land use plan | - | X | - |
| Availability of funds from different stakeholders | - | X | - |
| Availability of initial capital (e.g. poultry, seeds) | - | X | - |
| Availability of water harvesting experts | - | X | - |
| Adequate trained staff and experts | - | X | - |
| Existence of local catchment management by-laws | - | X | - |
| Existence of local extension system (e.g. DA, SMS) | - | - | X |
| Local government and non-government institutions | - | - | X |
| Government support and commitment to local initiatives | - | - | X |

## Linkages of action plan responses to national climate policies and strategies

The preferred responses in each area were linked to existing local- and national-level climate change policies and strategies to offer legitimacy and to support the implementation process. Linking also helps anchor the proposed adaptation initiatives within ongoing baseline development efforts (UNDP 2010). In Kenya, there are a number of key policies and strategies that the responses are linked to, such as the National Climate Change Response Strategy 2010, National Climate Change Action Plan 2013-2017 and Taita Taveta County Integrated Development Plan 2013–2017, among others. The most important national strategies for climate change in Tanzania for linking the preferred responses are the National Adaptation Programme of Action 2007, the Water Sector Development Programme 2005-2025 and Water Resources Management Act 2009. The policies guiding identified responses of the community-based climate change adaptation action plan in Ethiopia are, for example, the Agricultural Sector Policy and Investment Framework 2010-2020 and the Climate-Resilient Green Economy Strategy 2011. The key preferred responses across the target areas include catchment conservation and protection, strengthening community and institutional capacity, enhancing water resources management, promotion of alternative livelihoods and promotion of efficient and renewable energy sources. Specific activities to facilitate implementation of these responses are also linked to existing policies and strategies.

These national policies and strategies that also form the framework for the implementation of the community-based climate change adaptation action plans in the respective countries are by no means exhaustive due to the cross-cutting nature of climate change that requires mainstreaming of adaptation into different sectors. Furthermore, some of these national strategies may have been revised since the time of the study. Therefore, newly formulated or updated policies and strategies relevant to climate change adaptation should be considered for future studies within the target areas. Nonetheless, the discussed policies and strategies have played an important role in the climate change adaptation discourse by providing information and guidelines on local- and national-level vulnerabilities and adaptive capacity, existing adaptation projects, suggested interventions and approaches as well as designing institutions and laws and supporting implementation of interventions. Therefore, their critical role should be recognised for successful implementation of local and national adaptation projects.

## Expected results and desired long-term outcomes

Envisioning the desired long-term outcome of the community-based adaptation action plans is necessary to motivate stakeholders towards implementing the preferred responses and to establish their roles and responsibilities. In each area, the overall goal or vision and long-term objectives of the adaptation action plans were formulated to ensure focused action. In Taita Hills and Mount Kilimanjaro, the long-term objectives formulated to achieve the overall vision, and the expected results were quite similar. The objectives in both sites included improved environmental health, increased water availability, improved food security, improved living standards, enhanced awareness and capacity to implement conservation and adaptation responses and improved human health. However, in the Jimma area, the objectives included creation of awareness and introduction of alternative livelihood options to reduce land degradation.

In Taita Hills, the stakeholders' vision was '*a healthy environment which guarantees equal access to sufficient, reliable and safe water and food security for healthy communities and rich biodiversity within 5 years*'. The expected results of the adaptation action plan include increased availability and access to adequate water for domestic and agricultural uses; enhanced food security, improved crop yields and productivity for livestock; strengthened community capacity to participate in implementing adaptation responses; increased household income; reduced poverty; enhanced catchment conservation and protection; increased knowledge and awareness of conservation and sustainable technologies and improved human and livestock health. On the other hand, the vision of stakeholders in Mount Kilimanjaro was ‘*ensured sustainability of Miwaleni Springs to provide enhanced benefits to the community while contributing to economic and social development*’. The expected results of the adaptation action plan included increased availability and water supply for domestic and irrigation activities, enhanced food security, increased crop and livestock production, improved land management and cultivation practices, increased uptake of alternative sources of energy, creation of employment activities, increased household income, secure livelihoods and poverty reduction.

In Jimma Highlands, the overall goal of the adaptation action plan was related to the creation of alternative livelihoods and awareness-raising on soil and water conservation and family planning. Unlike in Taita Hills and Mount Kilimanjaro, the stakeholders in Jimma did not create a vision statement due to time constraints. However, they designed their expected results from the desired responses, which were considered as the objectives of the adaptation action plan. The expected results of the adaptation action plan included increased household and community income, reduced pressure on land resources, enhanced environmental conservation and reduced degradation, improved food security and high agricultural yields, improved market systems, increased water availability, increased forest cover, enhanced livelihood security, creation of employment opportunities, increased community knowledge and awareness and improved technology adoption. Overall, several themes seemed to recur among the desired long-term outcomes of the adaptation action plans across the sites. These included improved water availability and access, increased agricultural production, food security, environmental conservation, secure livelihoods, increased household income and poverty reduction. Therefore, it could be argued that facilitating the realisation of these outcomes through implementation of the designed community-based climate change adaptation action plans can contribute to the fulfilment of the majority of the aspirations of local communities for prosperity and well-being.

## Potential of exploratory scenarios to support climate-resilient development in the highlands and mountains

High-resolution climate change models in association with socioeconomic scenarios provide tools for a systemic approach to the complexity of interactions and feedbacks between climate and other environmental and socioeconomic factors. This complexity is more difficult to capture for the highlands and mountainous areas due to steep environmental gradients, which for tropical areas often translate into contrasting, and sometimes conflicting, livelihood strategies. Social-ecological-economic scenarios built around climate model projections can contribute to assess context and outcome vulnerability (O’Brien et al. 2007) and potential for enhancing future resilience.

There is a common understanding that climate action should adopt the sustainable development as overarching analytical framework (Shukla et al. 2017). This approach seems sensible for highlands and mountainous areas where exposure to hazards is associated with marginalization. Mountain and highland communities often experience remoteness or isolation, which in practice means scarce access to technology, information, services and markets and weak influence on decision making and trades. Towards this objective, scenario frameworks can contribute to anticipating the synergies and trade-offs of climate change action with other sustainable development goals at different scales and to exploring how to mainstream mitigation and adaptation concerns into a large range of 'non-climate' policies, such as food security, education and health.

Scenario frameworks that promote participation by multiple stakeholders can inform decision making on goals and expectations from different perspectives, contributing to avoid (selective) maladaptation or to exploit potential positive outcomes deriving from climatic changes (McDowell et al. 2016). In the context of mountains and highlands, the participatory approach is useful, for example, to solve potential conflicts around ecosystem service flows along the altitudinal gradient and at broader scale.

Scientific experiments to downscale Global Circulation Models into ensemble Regional Climate Models for more high-resolution projections of future temperature and precipitation have taken huge leaps with improved accuracy and reliability. Yet the application of high-resolution climate model outputs has some limitations at very fine scale, such as village communities, particularly for mountain areas where topography is complex while the supporting meteorological observations are not uniform across the landscape. Rather than for predicting changes and planning specific adaptation strategies, at community scale, model outputs can be used to inform about potential challenges and to build the capacity of anticipating changes and envisioning alternative strategies.

### High-resolution climate projections for Africa

AFRICLIM high-resolution ensemble climate projections for Africa were developed by the scientists from the University of York and Kenya Meteorological Department under the CHIESA project (https://www.york.ac.uk/environment/research/kite/resources/). The spatial database provides monthly grids of temperature and rainfall as well as summaries of temperature and moisture parameters under two representative concentration pathways, the intermediate emissions RCP4.5 and high emissions RCP8.5 scenarios for the middle (2041–2070) and late 21$^{st}$ century (2071–2100) at 1-km spatial resolution. The database builds on 10 General Circulation Models that are dynamically downscaled using five regional climate models and four contemporary baselines (Platts et al. 2014).

These high-resolution climate projections predict increasing average annual temperatures for all three target areas for both the coolest and warmest quarters of the year. Similarly, a unifying drying feature is predicted for the mean annual rainfall for the driest quarter of the year for these areas. For the Taita Hills in Kenya, the AFRICLIM climate projections visualized as changes in the mean annual temperature and rainfall between the baseline 1961–1991 and 2041–2070 periods predict a hotter future with wetter rainy seasons and drier or similar dry months. For Mount Kilimanjaro in Tanzania, a drying trend is observed, but the causes and longevity are unclear. For Jimma in Ethiopia, the mean annual rainfall is predicted to remain similar but the annual moisture index to become more arid under both representative concentration pathways. In general, there is high model uncertainty for rainfall in climate projections.

**Case study 2: Participatory scenario building using high-resolution climate projections**

Adaptation strategies to climate change at community level should target vulnerability reduction and resilience enhancement by building on local and traditional knowledge and integrating this with expert, model-driven knowledge (Field et al. 2014). The high uncertainty around climate model outputs makes it difficult to identify uniquely adequate adaptation pathways, in particular in the regions of the world subjected to other major socioeconomic and environmental changes. For example, Eastern African mountain social-ecological systems face the simultaneous challenge of uncertain climatic conditions and high population growth and land cover change rates. In this context, scenario analysis can contribute to address environmental and socioeconomic challenges while incorporating uncertainty and multiple dimensions (Peterson et al. 2003). Participatory approaches are encouraged to co-produce knowledge, raise awareness about potential future challenges and build consensus around possible solutions (Jurgilevich et al. 2017).

Scenarios were developed for the Taita Hills and Jimma target areas with the aim to 1) understand how local communities have coped with climate events in the past, as well as their readiness and capacity to anticipate future changes, and 2) develop alternative adaptation pathways in response to projected climate change (Platts et al. 2014) to assess potential implications for land use and land cover and, therefore, for biodiversity and ecosystem services.

A participatory scenario development framework that integrates local communities with expert knowledge from a bottom-up perspective was used (Capitani et al. 2016). The scenario framework enhances the participation and ownership by local stakeholders and, thus, the relevance and legitimacy of the final outputs, as well as social learning and empowerment of vulnerable groups. The framework consists of four main steps (Fig. 1), whereby experts engage local stakeholders in focus group discussions and mapping exercises to facilitate the analysis of the expected socioeconomic and environmental trajectories under climate change scenarios and alternative adaptation responses (qualitative), the expected amount of changes (semi-quantitative) and their spatial distribution (spatially explicit). Modelers translate this information into quantitative and spatially explicit scenarios, which are then refined after validation and feedback from stakeholders. The validation and feedback final session allows for critical reflection on potential scenarios impacts (e.g. on livelihood), ecosystem services and biodiversity. In Taita Hills and Jimma, about 30 participants in four multi-stakeholder workshops in each area were engaged. Three scenarios were developed for each area, the business as usual (BAU) and two alternative adaptation scenarios. Finally, scenario outputs were evaluated by a sub-group of the stakeholders engaged in the scenario process, and critical reflection followed on the potential implications for ecosystem services and biodiversity.

In the Taita Hills, increase of seasonal rainfall variability was perceived the major threat to local livelihood and ecosystem functionality. In a scenario lacking integrated strategies across sectors (e.g. water, land and pest management) and along the elevation gradient (BAU), human population and activities further concentrate in the middle and upper hills. This triggers cascade effects on remnant forest cover and dependent biodiversity, water regulation, crop productivity and food security. The alternative adaptation scenarios envisage either improved agricultural system (Food Production) or ecosystem services and biodiversity restoration (Green Integration) associated with different reforestation rates and improved land and water management. In Jimma, projected temperature increase is expected to disrupt the current livelihood system, particularly by affecting coffee production. In a scenario of adaptation failure against existing stressors (BAU), coffee production decline and maize expansion over forested areas are expected, along with land degradation. In this area, the alternative adaptation scenarios envisage different deforestation rate decreases and coffee production maintenance through either expansion of commercial plantations (Coffee Industry) or expansion of the agroforestry system (Agroforestry - Traditional Coffee management).

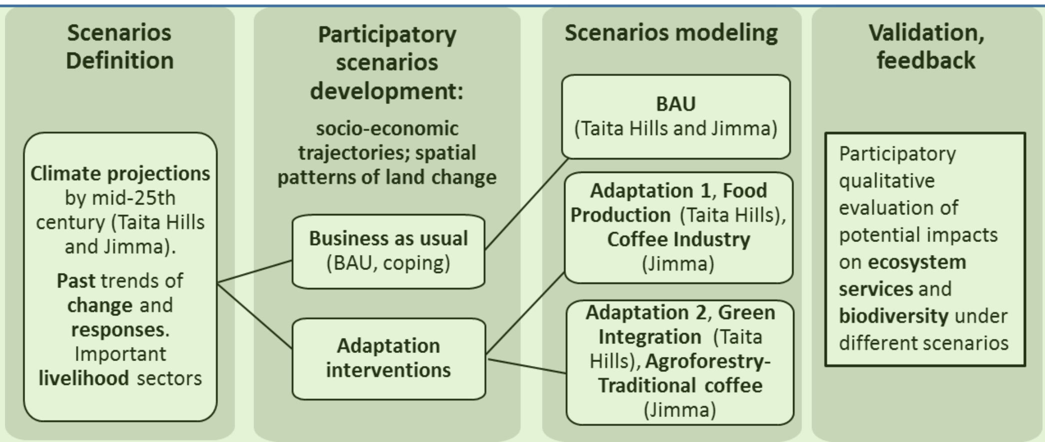


Figure 1. Application of the scenario framework (Capitani et al. 2016) to the Taita Hills and Jimma case study. Climate projections for mid–25th century under Radiative Concentration Pathway 4.5 derived from high-resolution spatial model products (AfriClim 3.0, Platts et al. 2014).

In both areas, the alternative adaptation pathways present trade-offs between provisioning (e.g. food), supporting (e.g. pollination) and regulating (e.g. climate and soil retention) services, biodiversity and socioeconomic transformation. Emphasizing transition towards agroecology and agroforestry could provide better trade-offs across multiple services. Likewise, social-ecological system resilience can be enhanced through synergies between climate change adaptation and sustainable development goals policies and implementation.

# Discussion

The co-production of knowledge for developing three site-specific climate change adaptation action plans in Eastern Africa facilitated and supported a dialogue among different local stakeholders who are often perceived to have competition over natural resources and to possess conflicting views about management, priorities and objectives. Previous studies (Vogel et al. 2007; Borquez et al. 2017; Olazabal et al. 2018) emphasize the value of co-production of knowledge and collective learning by different groups for building resilience, so this work further supports the approach. Integrated land and water resource management approaches, which have recently been incorporated into climate-smart agriculture and climate-smart landscape approaches, strongly emphasize multi-stakeholder involvement in all phases of the process cycle, from design and planning to implementation and evaluation. This is especially important in highland and mountain regions where climate change adaptation and mitigation plans and decisions implemented on the higher altitude zones or upstream of the river may have serious effects on the communities living in the valleys or downstream of the river. In the highlands and mountains, sustainable management of water resources is framed by the highland-lowland interactions and require sound and integrated knowledge for decision making and equitable negotiation of trade-offs between stakeholders (Providoli et al. 2017). For example, riparian area reforestation in the mountain slopes can help control soil erosion and, as a result, also reduce siltation of rivers and dams downstream. Multi-stakeholder involvement should operate on different geographical scales as well as on a broad set of sectors, including at least all climate-sensitive sectors in the target area, for example, within a drainage basin.

National climate change adaptation strategies do not often provide tangible guidelines for the grass-roots-level action to be implemented. Rather, the national strategies describe the general situation among different affected sectors, indicate normative actions and list responsible organizations for implementation. Such information remains superficial in the eyes of local stakeholders who do not necessarily have any tradition of cross-sector cooperation in ministries or other implementing agencies. In such cases, the process of implementing the strategy largely depends on external interventions and additional resources from the national government or from foreign donors. Dodman and Mitlin (2013) point out that the translation of climate change impacts into specific vulnerabilities are strongly dependent on local circumstances. This eventually means that the measures to build resilience have to be contextually rooted. In order to support climate-resilient development in the selected target areas of Eastern Africa, a specific initiative to co-produce community-based climate change adaptation action plans was launched. A bottom-up approach was selected to build upon local resources and inherent capacities of highland communities experiencing the impacts of climate change. The starting point was to establish cross-sector dialogue among different stakeholders to improve understanding of the dynamic interaction between people and their environment. This process was important for the empowerment of participants, and it also helped build awareness among the communities on differentiating climate- and human-induced drivers of change. Blaming climate change for every problem seems to be a common mechanism to externalize the cause and drivers of experienced negative change and, by doing so, to undermine the power of local actions and adaptive capacity to overcome the problems.

Community-based climate change adaptation action plans developed for the three target areas in Ethiopia, Kenya and Tanzania identified and recommended appropriate adaptation tools, instruments, technologies and practices for each individual area with different social-ecological characteristics and administrative systems. The process further built the capacities of local communities and stakeholders to implement various adaptation options, including conservation agriculture, drip irrigation, roof rain water harvesting, alternative cropping systems and biological pest control, through dissemination of research results and technology transfer, for example, by establishing demonstration plots. Much of the implementation of recommended actions can be started without any external inputs by utilizing the inherent capacities and local resources.

Although the co-production of knowledge and formulation of community-based adaptation action plans was central to the project, the action plan development process inherently generated valuable lessons and knowledge concerning local-level adaptation that can be applicable in similar social, environmental or political contexts across Africa and beyond. Field et al. (2014) recommend the integration of learning within adaptation projects for enhanced responses. Such lessons generated included an understanding of local communities' knowledge and perceptions on climate change impacts, adaptive capacities, local vulnerabilities and underlying causes of vulnerability. Furthermore, the process of using activities such as workshops, focus group discussions and field exchange visits offered an opportunity for equal participation of all stakeholders in the communities in making adaptation decisions suitable for different livelihoods and social groups.

## Conclusions

This study presented a process of developing a community-based climate change adaptation action plan to three different highland areas in Eastern Africa with an objective of building local communities' resilience to climate change. Participatory approaches were used to facilitate the integration of different knowledge systems, both scientific and indigenous, to understand climate change impacts at the local level and to prioritize adaptation actions and designate locations of most vulnerable areas for implementation. These action plans captured farmers' realities, local priorities and village-scale vulnerabilities to enable the grass-roots-level stakeholders and communities to have an active role in implementation and to establish locally based ownership of climate change adaptation initiatives. Community-based climate change adaptation action plans can also be useful in scaling down the goals of national climate strategies and making these more tangible for local context. Observations and results of this study encourage the use of multidisciplinary and multi-stakeholder approaches such as the proposed scenario framework for enhancing the capacity of local stakeholders to develop adaptation pathways in face of global challenges, identify and negotiate trade-offs between desirable and undesirable outcomes and build capacity for envisioning transformative changes towards more resilient future social-ecological systems. These approaches may produce more sustainable results with strong local ownership of processes and outputs.

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